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The Navigated Oblique Lumbar Interbody Fusion: Accuracy Rate, Effect on Surgical Time, and Complications

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Objective: The oblique lumbar interbody fusion (OLIF) can be done with either fluoroscopy or navigation. However, it is unclear how navigation affects the overall flow of the procedure. We wished to report on the accuracy of this technique using navigation and on how navigation affects surgical time and complications.
Methods: A retrospective review was undertaken to evaluate patients who underwent OLIF using spinal navigation at University of California San Francisco. Data collected were demographic variables, perioperative variables, and radiographic images. Postoperative lateral radiographs were analyzed for accuracy of cage placement. The disc space was divided into 4 quadrants from anterior to posterior, zone 1 being anterior, and zone 4 being posterior. The accuracy of cage placement was assessed by placement.
Results: There were 214 patients who met the inclusion criteria. A total of 350 levels were instrumented from L1 to L5 using navigation. The mean follow-up time was 17.42 months. The mean surgical time was 211 minutes, and the average surgical time per level was 129.01 minutes. After radiographic analysis, 94.86% of cages were placed within quartiles 1 to 3. One patient (0.47%) underwent revision surgery because of suboptimal cage placement. For approach-related complications, transient neurological symptoms were 10.28%, there was no vascular injury.
Conclusion: The use of navigation to perform OLIF from L1 to L5 resulted in a cage placement accuracy rate of 94.86% in 214 patients.

Keywords: Accuracy, Interbody fusion, Minimally invasive surgery, Navigation, Oblique lateral, Oblique lateral lumbar interbody fusion

INTRODUCTION

The prepsoas approach, also known as the oblique interbody fusion (OLIF) was first described by Mayer in 1997.[1] In 2012, Silvestre et al.[2] reported the complications and morbidities in 179 patients. Early data showed that bleeding, surgical time, and postoperative recovery had favorable results.[3] Historically, lateral lumbar interbody fusion (LLIF) has been done with a true lateral view under fluoroscopy, but the OLIF is done from an oblique trajectory.[4,5] This oblique angle can be somewhat disorienting for surgeons, and navigation may be one method to help abate this disorientation.[6] Although navigation has been reported as an alternative to fluoroscopy to perform the OLIF, there is limited data as to the accuracy of navigated OLIF in a large number of patients.[5] We wished to report how navigation affects the OLIF accuracy, complications, and surgical time.

MATERIALS AND METHODS

Retrospective review of medical records of patients undergoing navigated OLIF by 3 spine surgeons at our medical center from 2013 to 2018 was performed. The experimental protocol was approved by the Institutional Review Board of University of California San Francisco (IRB No. 18-25040), and patient consent was not necessary for this research. Inclusion criteria were: age ≥ 18 years, navigated OLIF from L1 to L5, and degenerative conditions of the lumbar spine, including deformity. Patients were excluded if they had tumor, infection, or trauma. Data collected were demographic variables, radiographic postoperative cage position, and approach related factors such as operative time, blood loss, and complications.

Accuracy and LLIF methods have been previously published by other authors, and we used their methodology to assess accuracy.[7-9] Their methods have been described elsewhere, but we briefly describe them here. To assess accuracy on postoperative lateral radiographs, the disc spaces were divided into 4 zones (1, 2, 3, 4) from anterior to posterior; zone 1 was anterior, and zone 4 was posterior (Fig. 1). The accuracy of cage placement was quantified by the cage position on postoperative radiographs. Because some cages are intentionally placed more ventrally to induce lordosis, we defined cage position in zones 1 to 3 as accurate. Because zone 4 is close to the canal, this has been previously defined this as not accurate.[9-11]

Surgical Technique

The patients were positioned in the right lateral decubitus position on a flat-top Jackson table, and the patient is taped securely at the greater trochanter and the shoulder. The left arm is placed into a thoracotomy arm holder, and the right arm is placed extended out laterally on an arm board extended out 90° from the bed. The right knee and ankle are padded with gel pads in order to prevent sores and damage to the right common peroneal nerve. The navigation camera is placed at the foot of the bed, and the posterior superior iliac spine (PSIS) is palpated and marked. After prepping and draping, a small stab incision is made approximately 2 inches posterolateral to the PSIS, and the navigation reference arc is placed. However, it is also possible to place the reference arc close to the anterior superior iliac spine. A single intraoperative computed tomography (CT) scan (O-Arm, Medtronic, Memphis, TN, USA) was performed with navigation registration (Stealth, Medtronic, Memphis, TN, USA). Using navigation, an incision was planned 5 cm anterior to the lateral mid vertebral body of the space or spaces of interest. Dissection was performed bluntly with direct visualization through the external oblique, internal oblique, and transversus abdominis muscles. The retroperitoneal fat was identified visually and swept ventrally along with the ureter. The anterior aspect of the psoas muscle was then dissected and swept dorsally as much as possible. This allowed a wider corridor of exposure and avoided traversing the psoas muscle and lumbar plexus. In addition, this allowed for correct, optimal position for docking of the retractor. Using navigation, the disc space was entered anterior to the psoas. Sequential dilators were inserted, and the retractor and light source were placed. The disc preparation instruments, the trial, and the cage itself were placed under navigation. A lateral fluoroscopic image was taken to confirm position of the cage at the end of the procedure. The retractors and the reference arc were removed, and the 2 incisions were closed in layers. Neuromonitoring was used at each step (Fig. 2).[5]

Fig. 1. The illustration shows how the disc spaces were divided into 4 quarters from anterior to posterior. This cage was placed in zones 2 and 3.

With regards to percutaneous screw fixation, the patient was subsequently positioned prone either on the same day or a subsequent date, depending on how extensive the surgery was. A reference arc was placed either in the iliac crest or on the spinous process, and another O-Arm spin was performed to register the navigation. Paramedian skin incisions were performed, and percutaneous screws were placed via the Wiltse approach into the lumbar pedicles (multiple companies: Depuy, Globus, Medtronic). The percutaneous rods were placed, and the incisions were closed in layers.

RESULTS

After review, 214 patients met the inclusion criteria, with 88

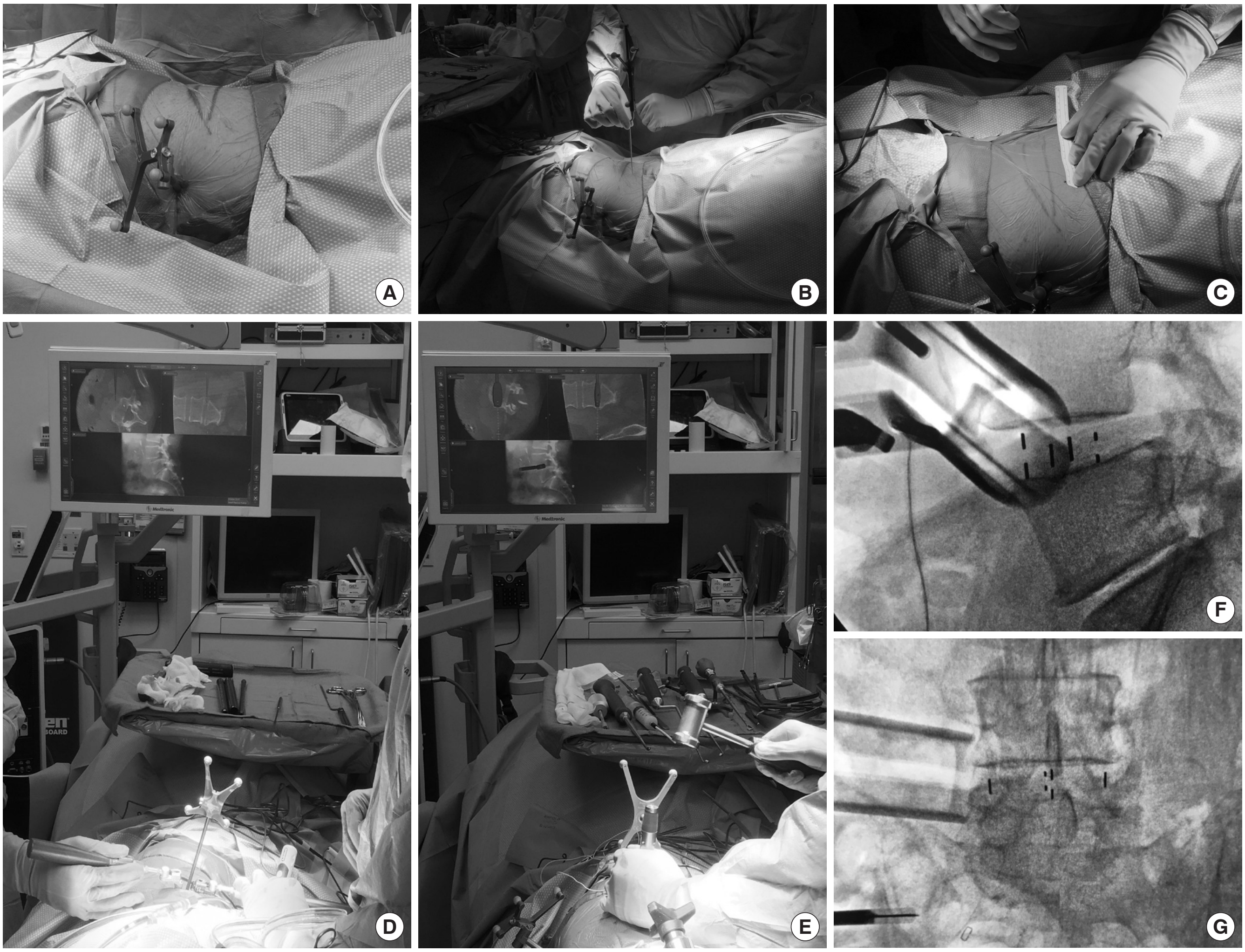

Fig. 2. The flow of navigated oblique lateral interbody fusion. (A) A reference arc was placed into the iliac crest via a small incision. (B) Using navigation to assess the position of the L4–5 disc. (C) The incision was planned 5 cm anterior to the lateral mid disc space. (D) Using navigation down to the disc space. (E) Disc preparation using navigation. (F) Cage insertion under navigation. (G) Fluoroscopic confirmation of the cage position in zones 1–2.

males (41.12%) and 126 females (58.88%). The mean age was 68.2 years, the mean body mass index was 28.54 kg/cm^2, and 14 patients were smokers (6.54%). The mean follow-up time was 17.42 months. The mean surgical time was 211 minutes, and the average time per level was 129.01 minutes. The mean blood loss was 90.72 mL per case, and the average blood loss per level was 55.47 mL. One patient (0.47%) underwent revision surgery because of suboptimal cage position. Table 1 shows the approach-related complications. There were 12 patients (5.61%) who had transient left thigh numbness after surgery, 3 patients (1.4%) had transient left thigh weakness, and 7 patients (3.27%) had transient left thigh or leg pain. There were 2 patients (0.93%) who suffered left abdominal incisional pain after surgery. One patient (0.47%) had a left psoas abscess, 2 patients (0.93%) had left psoas hematomas. Two patients (0.93%) had deep vein thromboses (DVTs) after surgery, 3 patients (1.4%) had postoperative ileus, and 2 patients (0.93%) had urinary retention. All of the above complications resolved after supportive treatment.

A total of 350 levels were fused from L1 to L5 using navigated OLIF (Table 2). There were 6 interbody fusions performed at L1–2, 72 at L2–3, 124 at L3–4, and 148 at L4–5. Twenty-one cages (6%) were placed in zones 1 to 2, 303 cages (86.58%) were placed in zones 2 to 3, 14 cages (4%) were placed in zones 3 to 4, 8 cages (2.29%) were placed in zones 1 to 3, and 4 cages (1.14%) were placed in zones 2 to 4. By defining zones 1 to 3 as accurate (indicating the anterior half or middle portions of the disc space), the accuracy rate was 94.86%.

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Table 1. Patient demographics and procedural data (n = 214)

Variable	Value
Sex	
Male	88 (41.12)
Female	126 (58.88)
Smokers	14 (6.54)
Mean age (yr)	68.2
Mean body mass index (kg/cm^2)	28.54
Mean follow-up time (mo)	17.42
OLIF including L5–S1	84
OLIF L1–5	130
No. of levels fused (L1–5)	350
Mean surgery times (min)	211
Surgery times per level (min)	129.01
Mean blood loss (mL)	90.72
Blood loss per level (mL)	55.47
Revision surgery	1 (0.47)
Approach related complication	
Transient left thigh numbness	12 (5.61)
Transient left thigh weakness	3 (1.40)
Transient left thigh/leg pain	7 (3.27)
Left abdominal incision pain	2 (0.93)
Left psoas abscess	1 (0.47)
Left psoas hematoma	2 (0.93)
Deep vein thrombosis	2 (0.93)
Ileus	3 (1.40)
Urinary retention	2 (0.93)

Values are presented as number (%) unless otherwise indicated.

Table 2. Radiographic results

Variable	No. of levels fused (n = 350)	No. of cages (%)
Levels		
L1–2	6 (1.71)	
L2–3	72 (20.57)	
L3–4	124 (35.43)	
L4–5	148 (41.29)	
Cage position* (zones)		
1–2		21 (6.00)
2–3		303 (86.57)
3–4		14 (4.00)
1–3		8 (2.29)
2–4		4 (1.14)

*The disc space is divided into 4 zones from anterior to posterior, 1–4.

DISCUSSION

The OLIF is a variation of the LLIF in that it does not traverse the psoas muscle and avoids the lumbar plexus. Appropriate cage placement is dependent on achieving an orthogonal orientation to the disc space. To obtain the correct orientation, biplanar fluoroscopy is can be used with lateral and anteroposterior views, which can be cumbersome and, can result in extended radiation exposure.[9] With the use of navigation, the OLIF procedure obviates the need for intraoperative fluoroscopy during the procedure. However, navigation may not always be accurate. First, there may be inaccuracy with the navigation itself, which may also be called inaccuracy that is intrinsic to the system itself. The navigation instrument is only calibrated to a certain accuracy because of the limits of the hardware and software. The second source of inaccuracy is extrinsic to the navigation system; there will be shift and movement with the patient over time resulting in inaccuracy even though the navigation system's accuracy has not changed. Because the reference arc is placed relatively far away from the surgical site, shifts in the spine, settling of the patient, and changes in alignment from surgical manipulation can lead to inaccuracy. Third, the minimally invasive approach itself may result in inaccuracy. This may seem counterintuitive because of the minimally invasive approach, but the orthogonal move (shifting the instruments from oblique to lateral) can place significant torque on the patient and on the retractor if not appropriately performed. Fourth, anatomic constraints can result in inaccuracy. For instance, if the psoas muscle is pushing on the retractor or the rib cage or the iliac crest are pushing on the retractor so that proper retractor placement is precluded, the anatomic constraints can also result in inaccurate placement of the cages. Thus, inaccuracies in navigation may affect the flow of the surgery, potentially increasing surgical time.[12-15]

Another fundamental question is what is defined as "accurate." Historically, the "safe" working zones for transpsoas surgery were based upon the location of the lumbar plexus. Uribe et al. demonstrated in a cadaveric study that for L1–2 to L3–4, zone 3 was the safest, whereas the midpoint of the vertebral body between zones 2 and 3 was the safest for L4-5[10,11]; however, in the prepsoas approach or OLIF, the position of the plexus is not as critical since the surgical approach is ventral of the psoas. Nonetheless, placement of the cage into the appropriate zones can be useful to (1) avoid disruption of the anterior longitudinal ligament, (2) to avoid encroachment upon the spinal canal, and (3) to allow for posterior compression to induce lordosis over the cage. Because of these above factors, we defined accurate placement if the cage was placed into zones 1 to 3. Using this method, Park et al reported their accuracy with navigation in 63 LLIF patients as 97%–98.3%.[7-9] In our series, only one patient had a revision surgery for a malpositioned cage, which gave us a revision surgery rate of 0.47%. We found that 94.86% cages were placed into zones 1 to 3, indicating that even cages placed into zone 4 were not always revised. Accuracy was only assessed from L1 to L5, and L5–S1 was excluded from the analysis. The L5–S1 OLIF does not use navigation, but uses fluoroscopy only. Since this manuscript focused on navigation, we did not include fluoroscopy-based levels (L5–S1). The other reason is that L5–S1 OLIF was not included is that the graft is placed in an anterolateral manner. Thus, there are no zones per se as in the L1–5 levels since the cage is placed as posterior as is necessary based upon fluoroscopy. For these reasons, the L5–S1 levels were excluded from the accuracy analysis.

With regards to the 1 case of cage repositioning, postoperative imaging showed that the cage was placed in zones 1–2, which was in the anterior half of the disc space. The patient also has symptomatic radiculopathy. It is unclear exactly what caused the inaccurate placement, but it may have been because the anterior longitudinal ligament had been ruptured, precluding containment of the cage, and because the disc space was extremely lordotic. Both factors may have resulted in suboptimal cage placement, but it is unclear how much navigation accuracy or inaccuracy played a role in this case (Fig. 3).

According to previously published reports on OLIF, transient neurological symptoms were reported to range from 6.1% to 21.4%, the incidence of left abdominal incisional pain was 2.2%, the rate of psoas hematomas were 1.4% to 4.8%, the ileus rates were 2.1% to 9.8%, and vascular injury rates were 1.6% to 2.9%.[16-18] In our series, the rate of transient neurological symptoms was 10.28%, which were defined as neurological symptoms that resolved within 30 days after surgery[16]; the rate of left abdominal incisional pain was 0.93%, ileus was 1.4%, and none for vascular injury. Other complications in our series occurred with comparable rates of other reports, with a rate of 0.41% of psoas abscess, a rate of 0.93% for DVTs, and a 0.93% rate of urinary retention. Compared to historical controls, many of which used fluoroscopy to perform the OLIF, navigated OLIF had either lower or comparable rates of postoperative complications.[16,17,19-22]

With regards to previously published reports regarding the accuracy of navigation, it has been shown that navigation during minimally invasive spinal surgery can reduce intraoperative radiation exposure to the staff and improve accuracy compared to fluoroscopy. In a review of the literature by Tian and Xu,[23] CT-based navigation systems had a pedicle screw placement accuracy rate of 90.76% versus fluoroscopic guided screws, which only had an accuracy rate of 85.48%. Matityahu et al.[24] reported accuracy in 130 percutaneous sacroiliac screw fixation cases, and there were no misplaced screws in the navigation group,

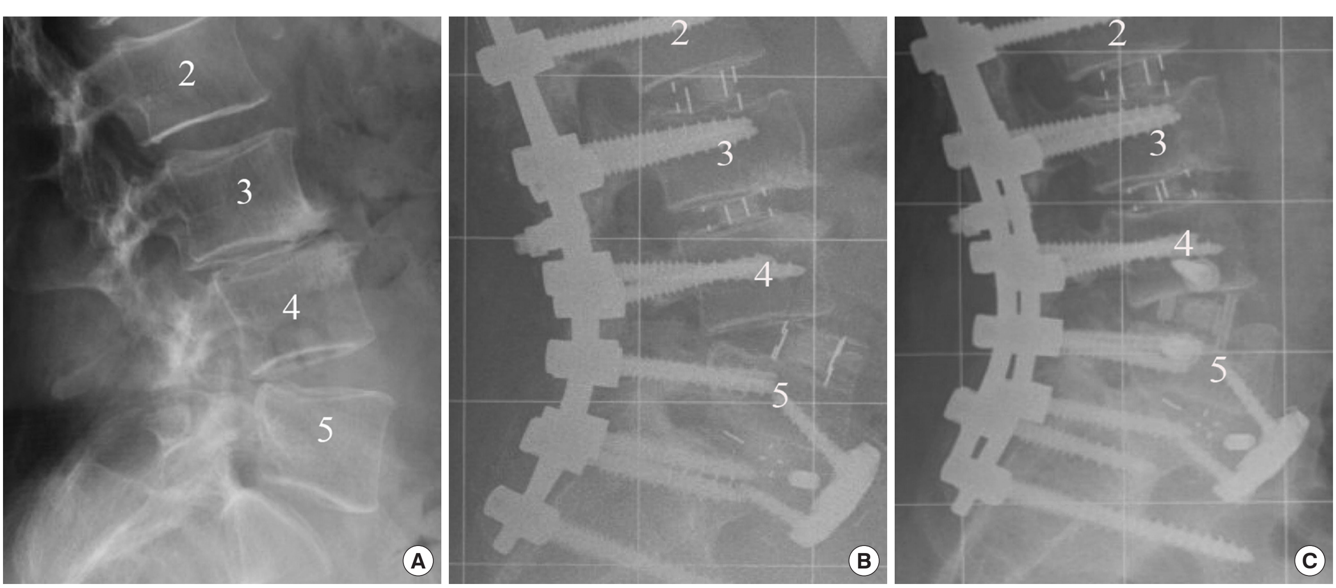

Fig. 3. Illustration shows the case images about the revision surgery. (A) Before surgery. (B) After the first surgery. (C) After the revision surgery.

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but 20.4% misplaced screws in the fluoroscopic group. With regards specifically to lateral cage placement rates, reported misplacement rates range from 0.26 to 3.8%.[25] Malham et al.[26] reported that 2.5% patients had iatrogenic leg pain potentially because of cage misplacement in 122 extreme lateral interbody fusion patients. Although there have been previous publications on OLIF and navigation, most of these papers did not specifically report cage placement accuracy.[5,6,27] However, Joseph et al.,[7] Liu et al.,[8] and Park[9] have previously reported navigation accuracy in LLIF surgery, and our findings are consistent with their previously reported accuracy rates. One issue, however, is the added radiation exposure to the patient with the second O-Arm spin for the pedicle screw fixation. Although there is increased exposure of radiation, the accuracy of the pedicle screw placement can be much higher, with Tajsic et al.[28] showing a 98.77% accuracy rate. In addition, for percutaneous pedicle screw fixation with navigation, Konieczny et al.[29] show an actual reduction in radiation exposure to the patient with navigation of up to 57% with increased accuracy when using navigation.

There were limitations to this study, however. First, this is a single institution, retrospective review. Second, there are no controls with fluoroscopy. Third, longer follow-up with a minimum of 2 years would have been ideal, but because of the relative novelty of OLIF and because the focus of this manuscript is about immediate postoperative placement, we included patients without 2-year follow-up. Fourth, with regards to the patient-reported outcome measures, this inconsistently available. Although we had attempted to obtain this information, the collection of this was not consistent, and we felt it would not be reflective of the entire cohort to report it on only a few patients. Another limitation is that there was no CT assessment of the accuracy, only radiographs. There are 3 reasons that we only evaluated the cage placement in sagittal position with radiographs. First, the main reason to have the cage in a truly lateral position instead of an oblique position is to avoid the contralateral nerve root. Upon imaging with lateral fluoroscopy or postoperative lateral X-rays, it can be seen that the cage is not posterior to the point that it could be causing impingement on the contralateral neural foramen. Because of this reason, we used only lateral radiographs to assess accuracy. Second, most patients do not have postoperative CT because of unnecessary radiation exposure and cost of the CT. Thus, it was not logistically feasible to calculate the axial orientation of the cages on CT since most patients did not have a postoperative CT. Third, we used a published methodology for the accuracy assessment of OLIF. Joseph et al.,[7] Liu et al.,[8] and Park[9] have reported their accuracy with navigation during lateral interbody fusion, and in their studies, they have compared the correlation of the cage position in axial, sagittal and coronal planes using the sagittal plane X-ray. Another limitation of this study is the lack of fusion assessment. For accurate fusion assessment, we would need 2-year follow-up and CT confirmation of arthrodesis with 2 independent reviewers. Because not all patients had 2-year follow-up nor did all patients have a CT, we could not accurately not comment on fusion without such data. One limitation with our study is the lack of controls comparing navigated OLIF with fluoroscopy-based OLIF. Part of the reason that there are no controls is that with the occupational hazards of radiation exposure to the surgeon and the operative team, navigation was used in all cases as opposed to the c-arm. It would have been more ideal to also have a fluoroscopy control subjects, but navigation was exclusively used in order to avoid radiation exposure. Because previous studies have shown that navigation did not prolong surgical time compared to fluoroscopy, all procedures were subsequently performed with navigation in order to avoid unnecessary radiation exposure.[5] However, one potential advantage of navigated OLIF is the ability to perform single-position anteriorposterior surgery at the same time. This is because the single reference arc can be placed, and the anterior interbody and the percutaneous screws can be placed in the lateral position. Although in our series, we did not perform pedicle screw insertion in the lateral position, this concept is certainly one advantage of navigated OLIF.

Finally, with regards to technical nuances to the navigated OLIF, there are 3 main points that may facilitate the procedure. First, the orthogonal move should be performed gradually, not necessarily all at once. Many times, the cage position needs to be altered as it is driven in, not changed all at once. Thus, slight manipulations of the cage during placement instead of a single, drastic move, can be useful for placing the cage into ideal position with navigation. Second, the orthogonal move can be used to compensate for either a very anterior or very posterior annulotomy. For example, if the psoas muscle is very anterior and precludes a normal annulotomy, cage can be driven in most posteriorly first, and the orthogonal move can be performed later. However, if the annulotomy is very posterior, the orthogonal move can be performed much earlier. Thus, by modifying the time and position of the orthogonal move, minor adjustments in cage placement can be made during the procedure with navigation. Third, if the prepsoas position is too anterior for an ideal OLIF, the psoas muscle can be bluntly swept dorsally to allow for a more ideal annulotomy. This can be done with a blunt dissector, and the annulotomy can be placed more posteriorly without violation of the psoas muscle itself.

CONCLUSION

Navigated OLIF appears to have a reasonable accuracy rate. In an analysis of 214 patients, 3 is a 94.86% cage placement accuracy rate in navigated OLIF from L1 to L5. For future studies regarding accuracy, a direct comparison with fluoroscopy-based OLIF and navigated OLIF with CT imaging of postoperative cage position can further delineate the true accuracy of this procedure.

CONFLICT OF INTEREST

Shane Burch, Consultant for Medtronic. Praveen V. Mummaneni, Consultant for Depuy Synthes, Stryker, Globus. Royalties: Thieme Publishing, Springer Publishing, and DePuy Synthes. Research Support: NREF, ISSG. Direct stock ownership in Spinicity/ISD. Dean Chou, Consultant for Medtronic, Globus, Royalty: Globus. Except for that, the authors have nothing to disclose.

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